UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
AD-A215 161	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
	5 MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR- 89-1502
6a. NAME OF PERFORMING ORGANIZATION Gordon Research Conferences Inc	6b. OFFICE SYMBOL (If applicable)
6c. ADDRESS (City, State, and ZIP Code) Kingston, RI 02881-0811	7a. NAME OF MONITORING ORGANIZATION AFOSR/NP
	7b. ADDRESS (City, State, and ZIP Code) Building 410, Bolling AFB DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR	8b. OFFICE SYMBOL (If applicable) NP
	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR-88-0208
8c. ADDRESS (City, State, and ZIP Code) Building 410, Bolling AFB DC 20332-6448	10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
61102F	2301	A4	

11 TITLE (Include Security Classification)
(U) 1988 GORDON CONFERENCE ON PLASMA CHEMISTRY

12 PERSONAL AUTHOR(S)
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13a TYPE OF REPORT	13b TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
FINAL	FROM 1 Jul 88 TO 30 Jun 89	October 1989	26

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	
	20.09		

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The 1988 Gordon Research Conference on Plasma Chemistry was held at Tilton School, New Hampshire, August 15-19, 1988. There were 139 scientists from the United States, Canada, Japan, Australia, England, France, Germany, Italy and the Netherlands in attendance. The conference was divided into nine sessions. Eight had two or three invited talks and two or three discussion papers with the total never exceeding five. The ninth session was a poster session which had 45 presentations. Two sessions dealt with the latest findings in low pressure, non-equilibrium plasma chemistry, covering the topics of plasmas in device technology, and plasma enhanced processing including diamond thin films and microwave plasma etching. One high pressure, thermal plasma session covered plasma processing for metallurgical applications and surface-plasma interactions. Six joint sessions included sessions on future plasma chemistry, nucleation and growth, plasma modeling, one each on diagnostics and new techniques in plasma synthesis/processing and the poster session. All the sessions were very well attended and generated much interest.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
X ☐ UNCLASSIFIED/UNLIMITED X ☐ SAME AS RPT ☐ DTIC USERS	UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL R E KELLEY	22b TELEPHONE (Include Area Code) (202) 767-4908
	22c OFFICE SYMBOL AFOSR/NP

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted.
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

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FINAL REPORT

TENTH GORDON RESEARCH CONFERENCE ON PLASMA CHEMISTRY

Tilton, NH, August 15-19, 1988

Alan Garscadden

Chairman, 1988 Gordon Conference on Plasma Chemistry

Advanced Plasma Research Group
Aerospace Power Division
Aero Propulsion Laboratory
Wright-Patterson AFB OH 45433-6563

I. Introduction

The 1988 Gordon Research Conference on Plasma Chemistry was held, as planned, at Tilton School, New Hampshire, August 15-19 1988.

Atch 1 is the main program of the conference and Atch 2 and 3 are the listings of poster papers for high and low pressure plasma chemistry respectively. A total of 143 persons preregistered for the meeting and 139 actually attended. Approximately twenty inappropriate or late applications had to be declined. (The maximum recommended by the Gordon Conferences is 135.) The attendance list (excluding guests) is given in Atch 4. There were scientists from the United States, Canada, Japan, Australia, England, France, Germany, Italy and the Netherlands.

The conference was divided into nine sessions, as detailed in the program. Eight had two or three invited talks and two or three discussion papers with the total never exceeding five. The ninth session was a poster session which had 45 presentations. Two sessions dealt with the latest findings in low pressure, non-equilibrium plasma chemistry, covering the topics of plasmas in device technology, and plasma enhanced processing including diamond thin films and microwave plasma etching. One high pressure, thermal plasma session covered plasma processing for metallurgical applications and surface-plasma interactions. Six joint sessions included sessions on future plasma chemistry, nucleation and growth, plasma modeling, one each on diagnostics and new techniques in plasma synthesis/processing and the poster session. All the sessions were very well attended and generated much interest.

The institution of formal committee and election procedures for the conference leadership that was begun with the Sixth Gordon Research Conference on Plasma Chemistry in 1980 was retained for this meeting. The nationally

distributed committee to organize the conference and to review submitted abstracts has raised technical standards and brought in a larger base of the plasma community. Financial support from the National Science Foundation has made it possible to attract both prominent scientists and junior faculty members who would otherwise have been unable to attend for financial reasons. The support from the AF Office of Scientific Research was used to bring in foreign speakers and to effect some reverse technology transfer.

The site chosen for the conference at Tilton School in Tilton, New Hampshire, has been very satisfactory. The location, layout and quality of the physical facilities at Tilton are excellent for a conference of this type. The location has few distractions but it is reasonably accessible. The lodging is frugal but costs are low. The resident manager from the Gordon Conference Headquarters and his staff were exceptionally helpful to the conference committee and did an excellent job. The overall positive atmosphere of the staff at the conference site contributed significantly to the success of the conference.

II. Historical Background

The present series of Biannual Gordon Research Conferences on Plasma Chemistry was established in the summer of 1970. The first three conferences, in 1970, 1972, and 1974, were devoted predominantly to the discussion of research and applications in the field of thermal plasmas. The conference attendance increased gradually to 76 participants in 1974. In 1975 and 1976, the amount of research work being carried out in the thermal plasma area seemed to be decreasing. This effect, along with organizational problems in the planning of the conference, resulted in a very poor conference in 1976 with only 43 participants and a very weak technical program.

In 1977 and 1978, two major events essentially re-established the conference and established a sound foundation upon which future conferences could be built. The first was in the area of conference organization and management. Responsibility for planning and running the conference was changed first from a single chairman to a chairman and a vice chairman, and then a chairman and a four-man committee. The second was the insight of the 1978 vice chairman in recognizing the importance of the emerging field of plasma processing of semiconductor materials. Interest in this area had spawned a new wave of fundamental research in this time period. Prominent scientists working at the state-of-the-art in the field were invited to speak at the conference. Attendance at the 1978 conference rose to 133 participants. For the 1988 conference, emphasis was placed on a sound technical program roughly 50:50 in the thermal and low pressure areas.

The 1988 conference continued the trend found at the conferences in 1980, 1982, 1984 and 1986 in that there were more applicants for attendance than the 135 participants considered optimum for a conference of this type.

III. Technical Program

The success of the technical program of this conference reflects the continued growing interest in plasma chemistry and processing and the continued improvement in the organization and technical standards of the conference. The conference was divided into nine sessions. The invited papers were selected by the members of the organization committee on the basis of the recent contributions of the speaker and the relevance of the paper to the current research area being discussed in the session. The discussion papers that were presented at the conference were selected by the organization committee from a considerably larger number of submitted

papers on the basis of the abstracts submitted. The addition of a poster session started in 1984 was repeated in the 1986 Conference with the same success. Before the 1984 Conference the most frequent complaint of attendees was that too many papers were scheduled into too small a time period leaving little or no room for true discussion. However, even with this overcrowding, many worthy and interesting discussion papers could not be scheduled due to time limitations. To alleviate both these problems during the 1988 conference, a poster session was scheduled on Tuesday evening, and some discussions initiated during this evening continued throughout the week. In this session, 45 posters were presented, all that the facilities would accommodate. This session was quite successful. Very good discussions developed around many of the papers and interest was very strong. The use of the poster session also allowed more time for discussion in the other sessions, which was likewise deemed good. However, it is felt that 45 posters were really too many for one session and for the space available. The dilemma is that researchers are pressured by their administrations and sponsors into feeling that they must present one or more papers. Some scientists were quite surprised when it was explained to them that their application acceptance did not require a paper but it did anticipate vigorous interaction in the discussions, formal and informal.

To facilitate discussion of the research work reported in the regular sessions, two discussion leaders were selected for most sessions by the organization committee. The individuals were chosen on the basis of their knowledge of the material being reported, in most cases they are active researchers in the field, and on their leadership abilities. The discussion leaders did a good job this year, participating where necessary and refereeing numerous interesting discussions during the sessions. As is typical of

this conference, important technical discussions also took place during the free periods in the afternoons and evenings. It should be noted that again in this conference six sessions were scheduled containing papers of interest to both low pressure and thermal plasmas. The success of this type of session is an indication that they should be continued. There were many favorable comments on the conference recognition of the fact that thermal and low pressure plasmas can usually be discussed easily in the same session. This also prevents the conference from dividing into two camps. The recent increased sophistication in thermal plasma modeling, including flow, surface interactions and unusual boundary conditions is quite remarkable. Considering the required investment for larger experiments, this capability of detailed modeling to give assurance to the reactor designer, and to funding sources, is very encouraging.

IV. Organization

Up until the time that organizational difficulties were encountered at the 1976 conference, the conference was planned and run by only a chairman or at most a chairman and a vice chairman. The conference vice chairman was automatically designated chair of the succeeding conference. The vice chairman, in turn, was appointed by the prevailing chair. While some chairmen conscientiously attempted to choose a successor who would maximize the success of future conferences, others simply selected a friend. In any event this arbitrary process failed; clearly the organization of the conference is too important an issue to be entrused to a single individual.

During the 1978 conference, procedures were formulated and adopted to have the conference run by a five-person committee. The appointed members were selected on the basis of their ties to the plasma community,

organizational abilities and technical research acumen. To attain a balance between non-equilibrium and thermal representation, members were chosen from both the thermal and non-equilibrium research communities. It was agreed at that time that all members would vote on selection of conferees and papers. The full committee also assisted in locating outstanding ongoing research deserving of presentation and in disseminating information regarding the conference to the international community. Decisions were reached by a consensus of the members. Sometimes, three or four of the committee members met in person at society meetings during the year. On occasion, the chairman simply polled each committee member for his option, by phone. Members of the plasma chemistry community outside the formal committee were also solicited for suggestions. This was especially useful for overseas speakers who must be contacted early.

The organization committee for the 1988 conference represented a strong mix of backgrounds from both the thermal and non-equilibrium plasma areas and the academic and industrial environments. The committee was composed of Alan Garscadden, Conference Chairman and a research physicist at Wright-Patterson AFB and adjunct professor at the Department of Physics at the Air Force Institute of Technology and several universities, Richard Munz, Conference Vice Chairman and professor at McGill University, Richard A. Gottscho, senior scientist at AT&T Bell Laboratories; Tom Meyer, senior scientist at ALCOA, Pittsburgh; Hendrik Oskam, professor in the department of Electrical Engineering, University of Minnesota, and the chairman of the 1986 conference. The members of this committee did an outstanding job of planning and executing the 1988 Conference, and the chairman wishes to express his appreciation to them all.

The elected Committee Members for the 1990 Gordon Research Conference on Plasma Chemistry are:

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The election of the above members presented some concern to some established members of the thermal plasma community in that they felt that it would be fairer to have at least two of the committee members definitely from their ranks. Reassurances were made that the conference chair and committee had always strived to give the thermal plasma community approximately 50% of the program and that this would continue. However, this was not accepted as satisfactory. On the other hand, it is definitely not in order to retroctively change the results of an election. It is possible to alleviate

the concern by coopting one or more additional members to represent the thermal plasmas or at the next conference to establish a rule that two must be selected from each side of the conference. There are advantages and disadvantages to all of these suggestions and to the present arrangement. One would prefer to emphasize the links and commonality between the technologies rather than perceived differences. This is actually illustrated by the success of the increased number of joint sessions. Also, it must be realized that the program selection depends on the input from all of the community and that it is finally judged on technical merit with most evaluators being harder on areas with which they are most familiar. In any case, this is a problem which we are sure can be resolved as the new committee is quite flexible. The apprehension demonstrated by the several members of the thermal plasma community indicates that the committee should be sensitive to other representations, such as the European and Japanese attendees.

For the organization of the conference to proceed effectively, a specific timetable must be followed. The recommended timetable that has been sent to Dr Phelps is

Strawman program	Nov-Dec 1988
Chairman's meeting in NY	Feb-Mar 1989
Proposal drafts	Jan-Feb 1989
Revise mailing list	Mar 1989
Foreign contacts for speakers/discussion leaders	Apr-Jun 1989
Submit proposals	Jul 1989 for FY90 $
US contacts for speakers/discussion leaders	Jul-Sep 1989

Confirm foreign speakers	Sep 1989
Draft program & budget	Oct 1989
1st Announcement	Oct-Nov 1989
Confirm US speakers Check on proposal status	Nov 1989
Forward program to GRC To be Published in Science	31 Dec 1989
Revise final program if necessary. Select discussion papers Revise budget	Jan-Mar 1990
Distribute program to speakers and discussion leaders	Apr 1990
Second announcement-possibly information only. It may not be necessary to solicit any more participation as meeting is usually oversubscribed	Apr 1990
Select poster papers	May 1990
Finalize budget	May 1990
Check on proposal status	Apr 1990
Reconfirm $ and arrangements with foreign speakers	May 1990
Weekly registration lists (use telephone acceptance after 10 June)	Apr-Jul 1990

VII. Conclusions

The 1988 Gordon Research Conference on Plasma Chemistry was a very strong and successful conference. The conference received an excellent rating by the attendees, actually the highest so far. It was judged to have been largely successful in establishing good, direct communications between scientists working in particular areas and also cross-communications between different aspects of plasma chemistry.

As will be noted from the attendance list, there was an excellent representation from industry and universities in the U.S. and also Europe and Japan. The range of topics was deliberately broad and most of the invited speakers delivered talks that were state of the art. We were helped a lot by the identification of Japanese and European speakers who spoke colloquial English and who were practicising scientists. Some excellent papers also came from the Canadian representatives who are conscious of the role that plasma processing can play in their low cost hydroelectric economics of Quebec and Ontario (especially in thermal plasma processing). The Japanese papers included valuable contributions from low pressure plasma technique used in microelectronics and also from high pressure plasmas used in surface treatments of aerospace alloys. The plasma jet devices are used for spray coating, cutting and welding at power loadings up to 100 kw. There were also some French reports on chemical processing at higher power loadings for hydrocarbon cracking. The high pressure arc discharges attain temperatures between typically 5000 to 50,000°K. The heat content approaches 200,000 BTU/lb. Tioxide Inc is routinely using megawatt arcs for titanium oxide production. While there is still good experimental and theoretical expertise in the U.S. in arc physics (Univ. Minnesota, Westinghouse, GTE) the field has declined in terms of participants. The 1986 NSF Workshop on Thermal Plasma Systems outlined the many advantages of the technology and also showed the implementation of the methods by many overseas companies. The advances reported at the GRC on modeling of both the physics of, say, plasma-particulate interactions and even of complete system performance were very impressive. It appears that the reluctance to change from traditional methods in materials processing may be overcome by these

convincing models and the competition from Europe and Japan. One aspect that appeared from the GRC discussions is that there is a need for a thermal plasma technology data base. These exist to some extent at the various research centers, however, there is not equivalent to the NBS (NIST) cross-section information provided by NBS/Univ of Colorado or by the plasma fusion community for fusion data and materials interactions. Some of the existing codes (e.g. Libermann's) are proprietary to his company. It is also not clear what will happen when such an individual retires.

The low pressure plasma processing area has seen an explosion of interest. The new technologies benefitting from plasma processing include etching, multilayer devices, high temperature superconductors, detector arrays, thin-film diamond or diamond-like layers, and sterile thin polymer layers for special applications. An elegant and simple technique reported by Tachi of Hitachi, Inc. was the use of cryogenic cooling of silicon substrates to decrease the isotropic etch. Kerfs as high as 22 at 0.3 microns were illustrated. Other papers illustrated a significant Japanese effort in exploring microwave excited discharges as sources of etching radicals. The advantages are high fluxes of atoms or radicals and small bias potentials so that ion bombardment damage is not a problem.

A spontaneous data base for etching plasmas and low pressure plasma chemistry is being promoted by several attendees, notably Drs J. Herron and L. Kline. The number of attendee positions that are available is actually quite limited. Thus, the committee and elders of the conference typically take 10 slots, the invited speakers 20 slots, discussion speakers 20 slots and the discussion leaders 20 slots. This leaves 65 attendee slots.

The informal rule used this year was that no one group should appear to have extra privileges. Thus, committee papers were all poster papers

and only one oral paper/group should be accepted. Where it is appropriate some people should feel quite free to attend the Gordon Conference without submission of a paper.

One surprise is the relative rigidness of the program, i.e., the number of sessions is nine, and if two are set aside for posters this leaves five morning sessions and two evening sessions. Three formal speakers are recommended for each morning and two for each evening. This means that only 19 long talks are possible. If one develops the conference around themes then about six or seven are required. Two of these should be new items or themes that are of high interesting 1990, and at least three (including the former) should be themes that are of interest to all communities of the conference. With the strength and diversity of leadership in the new organization committee, we expect another outstanding conference in 1990. The field is certainly entrinsic and of basic and applied interest.

The conference received support from Dr Robert Goulard, NSF, Thermal Systems and Engineering Division and from Dr Ralph Kelley, Air Force Office of Scientific Research, Physics Directorate. In some contrast to earlier meetings, rather than fully sponsoring travel and expenses of a few overseas speakers, at this conference we covered the registration and expenses (excluding travel) of the overseas visitors and of the U.S. university attendees. Thus, the expenses were shared for most attendees except for those employed by large companies or by government. This was felt to be in the spirit of the Gordon Research Conferences where one is encouraged to include the next generation of physicists and well as the present experts.

GORDON RESEARCH CONFERENCE
PLASMA CHEMISTRY

Tilton, New Hampshire
Tilton School

15 August 1988

Monday 9:00 a.m.	D.R. MacRae, R. D'Agostino Discussion Leaders : Future Plasma Chemistry
	H.Winters : Plasma-Surface Interactions
	J. Goodwill : Metals Production via Thermal Plasmas
	Discussion Papers:
	Savkar and Siemers : Rapid Solidification Plasma Deposition
	L.C. Lee : Electron Kinetics & Spectroscopic Data of Molecules
	H. Sawin : Experiments and Model for RF SF6 Discharges
Monday 7:30 p.m.	Osamu Matsumoto, Discussion Leader : Plasma Enhanced Processing
	P. Bachmann : Diamond Thin Films
	Shin-Ichi Tachi : "Low Temperature RIE and Microwave Plasma Etching"
	Discussion Papers:
	Kroesan and Schramm : Dynamics of an Expanding Arc Plasma used for Plasma Deposition
	Matsumoto : Deposition of Diamond from CO-H2 Mixtures in a Microwave Discharge

16 August 1988

Tuesday 9:00 a.m.	E. Pfender, H. Suhr, Discussion Leaders : Nucleation and Growth
	M. Mandich : Silicon Cluster Studies
	S. Girshick : Nucleation and Growth in Thermal Plasmas
	B. Bagley : Plasma Oxidation of the High Temperature Superconducting Perovskites
	Discussion Papers:
	Kong and Pfender : Synthesis of Fine Ceramic Powders in a DC Plasma Using a Novel Liquid Injection Method
	Buss : Laser Studies of SiH Radical Interaction with a-Si:H Surface
Tuesday 7:30 p.m.	Poster Session (Organizers R. Munz & R. Gottscho)

17 August 1988

Wednesday 9:00 a.m.	M. Boulos, D. Graves, Discussion Leaders : Plasma Modeling R.W. Liebermann : Thermal Plasma Models and Codes J.P. Boeuf : RF Discharge Models Discussion Papers: Mostaghimi and Boulos : Two Dimensional Electromagnetic Field Effects in Induction Plasma Modeling M. Kushner, L. Kline : Models of Plasma Deposition and Etching
Wednesday 7:30 p.m.	A. Hare, T. Yoshida, Discussion Leaders : Surface-Plasma Interactions M.G. Drouet : Electrode Erosion Studies Discussion Papers: Johnson et al : Chemical and Thermal Effects in the Plasma Sintering of Ceramics Bouabdeli, Pateyron and Fauchais : Study of a Fluidized Bed Heated by a DC Plasma Jet Tsantrizos and Gauvin : Cathode Deterioration Phenomena in a Transferred Arc Reactor

18 August 1988

Thursday 9:00 a.m.	G.K. Herb, Discussion Leader : Plasma Device Technology A. Harrus : Plasma Assisted Deposition and Device Technology G. Oehrlein : R.I.E. Surface Damage to Electronic Materials M. Geis : Diamond-Based Devices M. Hirose : Plasma Deposition of Semiconductor Multilayer Structures
Thursday 7:30 p.m.	Van de Weijer, T. Miller, Discussion Leaders : Plasma Diagnostics J.T. Verdeyen : Practical Microwave Diagnostics of Plasma Reactors W. Roman : Diagnostics of Processing Plasmas Discussion Papers: D.L. Smith : Special Mass Spectrometric Techniques for Plasma CVD Analysis Moneuse and Kassabji : Laser Diagnostics for High Power Thermal Plasma Processes J. Wormhoudt : Laser Diagnostics of Microelectronics Fabrication

19 August 1988

Friday 9:00 a.m.

P. Fauchais, Discussion Leaders : New Techniques in Plasma Processing
Y. Manabe : Thin Film Deposition Using ECR Plasma
K.S. Mazdiyasni : Fine Powder Synthesis
Discussion Papers:
G. Kaganowicz : Low Cost Process for Fabricating Polysilicon Transistors
Etemadi : Thermal Plasma Crystal Growth
Amouroux : Plasma Hydrocracking of Heavy Hydrocarbons

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Committee: R.L. Munz
T. Meyer
R.A. Gottscho
H.J. Oskam

POSTERS HIGH PRESSURE

AUTHOR	ORGANIZATION	TITLE
Amoroux	ENSCP, France	Production of ultra pure Si and Ti
Amoroux	ENSCP	Chemical reactivities of carbon monoxide excited by electrical discharge
Boulos	Sherbrooke, Canada	Induction plasmas; modelling and experiments
Coudert	Limoges	Temp. Meas in low pressure nitrogen jets
Czernichowski	U. Orleans, France	Plasma assisted vaporisation of light hydrocarbons and some waste products
Czernichowski	U. Orleans	AC and DC high pressure electroburner and some of its applications
Etemadi	SUNY	Modeling of a free-burning arc in the presence of copper vapour
Fauchais	Limoges, France	Exptl drag and heat transfer
Fauchais	Limoges	Melting of ZrO2 in dc jet
Harry	UK of Tech Loughb	High power atmospheric pressure glow
Lecuiller	CNRS, France	Nitric Oxide Formation in Coronas
Meunier	McGill U, Canada	Axial Magnetic positioning of arc foot in a plasma torch
Okazaki	Sofia U, Tokyo	Rate of ozone formation and augmentation of ozone prod by SF addition
Parisi	McGill Univ, Canada	Heat transfer to a cylindrical enclosure
Peeling	Tioxide, UK	Predicting the characteristics of gas vortex stabilized arc heaters
Pfender	Minn	Gas composition effects of sintering

POSTERS HIGH PRESSURE (continued)

AUTHOR	ORGANIZATION	TITLE
Pfender	Minn	Velocity measurements in a thermal plasma jet
Sheinson	Naval Research Lab	Air pollutant destruction mechanisms in discharges
Scott	CSIRO	Temperature in the plume of dc plasma torch
Mitsuda Yoshida	U. Tokyo	Diamond systhesis from the Gas Phase

POSTERS LOW PRESSURE

AUTHOR	ORGANIZATION	TITLE
Amoroux	ENSPCP	Elementary processes for TiN growth inder NH3 low pressure cond.
Anderson	U. New Mexico	Low temp low pressure rf synthesis of SiN ceramic precursor powders
Avni	Ben Gurion U	Mechanism of surface boridation of monolithic ceramics...
Becker	Lehigh Univ.	Dissociative electron collisions with CC12F2...
Cramarossa	Bari, Italy	Glow dis. dep. of a-Si:H from SiH_4-H_2 mixtures
Derouard	U. Joseph Fourier Grenoble, France	Space and time resolved optical diagnostics of glow discharges
D'Agostino	Bari, Italy	Effect of negative bias on plasma deposition
Evans	GEC	Rotation of a low pressure glow discharge in a transverse magnetic
Fujimura	Fujitsu ltd	Impurity effects on oxygen downstream ashing
Gottscho	Bell Labs N.J.	Photoemission optogalvanic spectroscopy
Haaland	Harvard/USAF	Ion kinetics in silane plasmas
Kroesen	Eindhoven/Netherlands	In situ elipsometry during plasma etching of SiO2 films
Matsumoto	Aoyama Gakuin Japan	Deposition of polymer film by ECR plasma CVD method
Miller	OSU	Hydrogen atom measure in rf plasma discharges
Okazaki	Sofia U., Tokyo	Estimation of surface structure by plasma fluoridation

POSTERS LOW PRESSURE (continued)

AUTHOR	ORGANIZATION	TITLE
Phelps	U of Colorado	Role of ion and fast neutral collisions in low pressure
Srivastava	Jet Propulsion	Cross sections for the prod. of pos and neg ions by electron impact
Turban	CNRS Nantes	Reactive plasma etching of Si and W in SF6-N2 mixtures
van Weijer	Philips Eindho	Chemiluminescence during chemical vapour deposition of SiO2 from sila
Kammermaier	Siemens, Germany	Emission spectroscopic analysis in low pressure plasmas for deposition
Michels	United Tech.	Potential Energy Surfaces for Silane Ion-Molecule Reactions
Bouchoule Ransor	Grem: Lab. Orleans	Time-Resolved Spectroscopic Studies in pulsed low pressure reactive plasmas
Bocker Lergon	Essen Univ W. Germany	Experimental investigation of the relaxation of the plasma-wall sheath
Mandich	Bell Labs	Deposition of high T_c thin films
Shoemaker Ganguly Garscadden	USAF	Rydberg State Spectroscopy

CONFERENCE #: 88-S-TS-10
CONFERENCE LOCATION: TILTON SCHOOL

CONFERENCE TOPIC: PLASMA CHEMISTRY
CONFERENCE DATE: AUG-15-88

CONFERENCE CHAIRMAN: ALAN GARSCADDEN

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Dr Julian J. Hsieh	AT&T Bell Laboratories
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